Wind and Wave Induced Responses of Double-Hinged Articulated Loading Platform (ALP)

by

Mohd Moonis Zaheer

Research supervisor

Dr. Nazrul Islam
(Professor)

ABSTRACT

An articulated loading platform (ALP) is one of the compliant offshore structures, economically attractive under deep water conditions. It consists of a buoyant shaft, connected to the sea bed through a universal joint. The part of the tower emerging from the water surface supports a superstructure arranged to suit a particular application, e.g., tanker's mooring and control tower. To further economize the structure for deeper water, one or more intermediate hinges are introduced leading to a configuration called multi hinged articulated tower. Present study deals with the investigation of the dynamic response of a double hinged ALP under wind and waves. A general purpose computer program "Double Hinged Articulated Loading platform, DHALP" has been developed for the dynamic analysis of multi hinged articulated towers.

Response of double hinged ALP to random wave and current forces is determined by using modified Morison's equation. Monte Carlo simulation technique is adopted to model the random sea environment. Time traces and power spectra of the responses under large and moderate sea states show the wave and low frequency responses.

A significant quantum of work is dedicated to the evaluation of wind forces on large exposed area of the platform superstructure. The wind structure interaction model is given in terms of single-point and multiple-point wind field. Wind and waves are

assumed to be correlated. Three different wind velocity spectrums, viz; Ochi and Shin, Simiu and Davenport are used to model random wind loads while, P-M spectrum is used to model random wave loads. Responses are obtained for three sea states under various wind velocities varying from 10 - 25 m/sec. Significance of multiple-point formulation viz-a-viz single-point formulation has been established after comparative assessment of dynamic responses. The results also highlights the conditions under which wind induced vibrations assume significance. The dynamic response in surge due to wind excitation is also analyzed with different sea surface roughness formulations. The dynamic response has been computed as a function of various parameters, such as wave age, damping ratio and the mean wind velocity at 10 m elevation. Application of the Volkov versus the Charnock model for the sea surface roughness parameter was found to have a significant effect on the surge response.

Reliability assessment of articulated joint against fatigue damage caused by wind and wave fluctuations has also been carried out. Nonlinear limit state functions using Palmgren-Miner's rule and Fracture Mechanics approach have been derived in terms of various random variables. Advance FORM and Monte Carlo methods are employed for the reliability assessment. Probability of failure and reliability indices is obtained for twelve different sea states covering the stipulated service life of 25 years. A comprehensive parametric study is carried out to show the effect of important parameters on the reliability. It is found that S-N curve approach yields a conservative estimate of probability of failure as compared to the fracture mechanics approach.

The parametric investigations indicate that the dynamic and reliability analyses of double hinged ALPs for wind and wave induced forces should form an important consideration in serviceability and safety of the design of such offshore towers. Serviceability and survivability of the platform due to these effects is highly sensitive to the variation of parameters influencing the computation of dynamic response and fatigue damage. Because of these reasons, dynamic and reliability analysis of ALPs for wind forces deserves due consideration at the design stage in order to minimize the operational, societal and economic risks.